# The EUMETSAT Satellite Applications Facility for NWP (NWP SAF)

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JCSDA presentation 17th April 2007

# Outline

o Background / Mission / People

o Projects:

- AAPP
- RTTOV
- 1D-Var
- Quickscat Data Processor/ SDP
- Monitoring reports
- SSMIS_Preprocessor
- Support to EARS

o Conclusions

# NWPSAF background

- Other SAFs include: ocean & sea ice, climate, ozone and Gras
- NWPSAF delivers software modules for use in DA systems ( other SAF's develop products)
- Phases include :
  - 5 year dev phase (1998 - 2003)
  - 3 year initial operational phase (2003 -2006)
  - continuous dev and operations phase (2007 - )
- Management : Steering group
- Software development under quality systems (dedicated QA/QC at local level, review process)
- Visiting scientists (to accelerate the development of deliverables / training 1 day -2 years)

# The NWP SAF: background

- Satellite Applications Facility for Numerical Weather Prediction (**NWP SAF**)
  - one of 8 SAFs that form part of the distributed ground segment of EUMETSAT
- Led by the **Met Office**, in partnership with **ECMWF, KNMI** and **Météo-France**
- 75%-funded by **EUMETSAT**

# The NWP SAF: mission

## MISSION

- To improve and support the interface between satellite data/products and European activities in global and regional NWP

# The NWP SAF: people

- **Manager:** B.Conway
- **Project Team:**
  - **Met Office:** S.English, R.Saunders, D.Offiler, N.Atkinson, W.Bell, J.Cameron, B.Candy, A.Doherty, M.Forsythe, P.Francis, R.Francis, F.Hilton, S.Keogh, U.O'Keeffe, E.Pavelin, P.Rayer, S.Watkin
  - **ECMWF:** T.McNally, P.Bauer, A.Collard, A.Garcia-Mendez, H.Hersbach, G.Kelly, J.-N.Thépaut, G.Van der Grijn
  - **Météo-France:** P.Brunel, T.Labrot, L.Lavanant, P.Marguinaud, A.Marsouin
  - **KNMI:** A.Stoffelen, A.Verhoef, J.Vogelezang
- **Steering Group:** J.Eyre, L.Sarlo, S.Elliott, J.Onvlee, P.Pylkko, F.Rabier, P.Schluessel, A.Simmons
- **Visiting scientists:** Many!

# The NWP SAF: products

## At present:

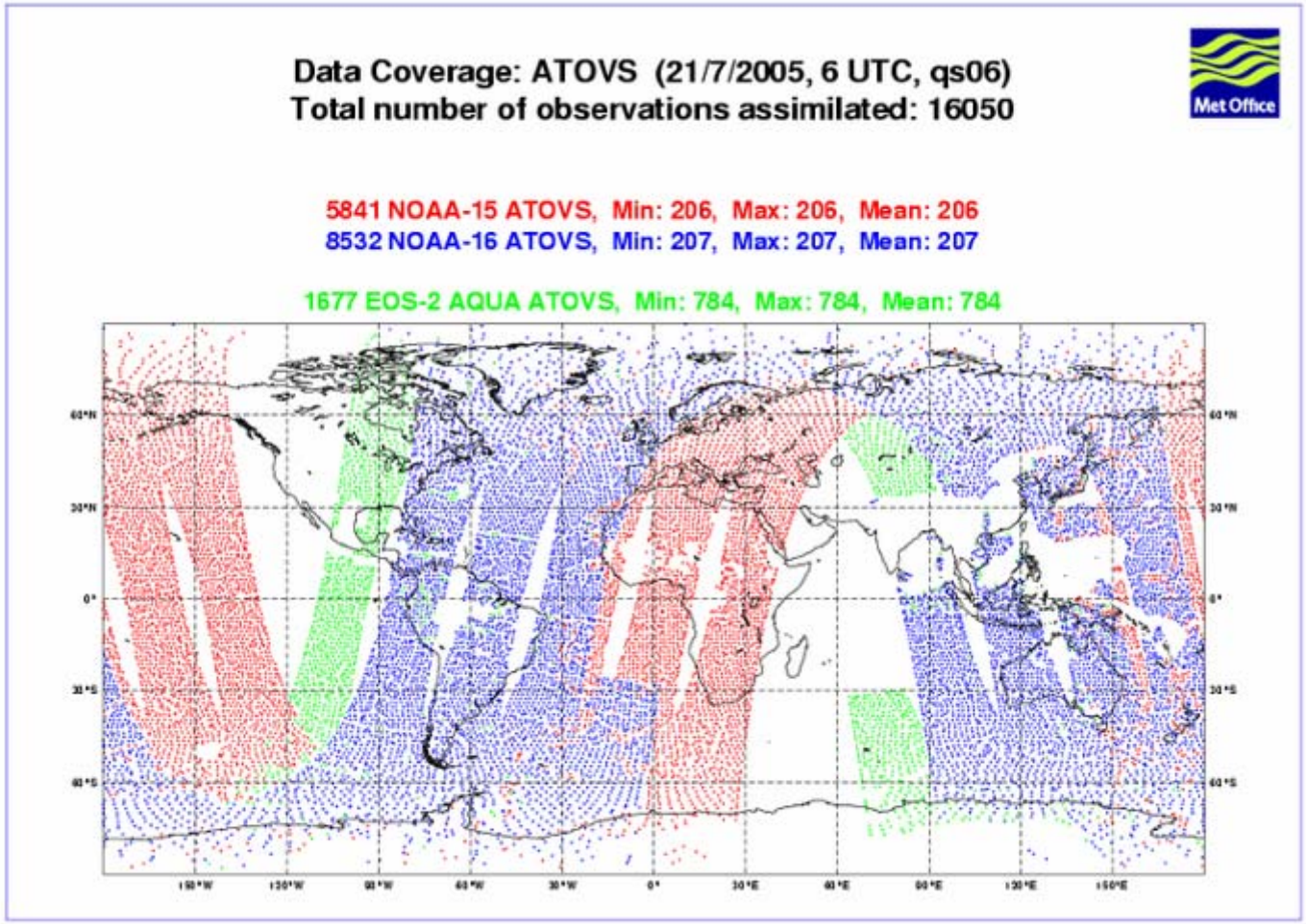
- **AAPP** - ATOVS and AVHRR Pre-processing Package
- **RTTOV** - fast radiative transfer model
  - + model-based profile data sets
- **1D-Var** retrieval schemes
- **QDP** - Quikscat Data Processor
- **Monitoring reports**
- **SSMIS pre-processor**

## Under development:

- **Updates** to the above
- **SDP** - Scatterometer Data Processor

# AAPP

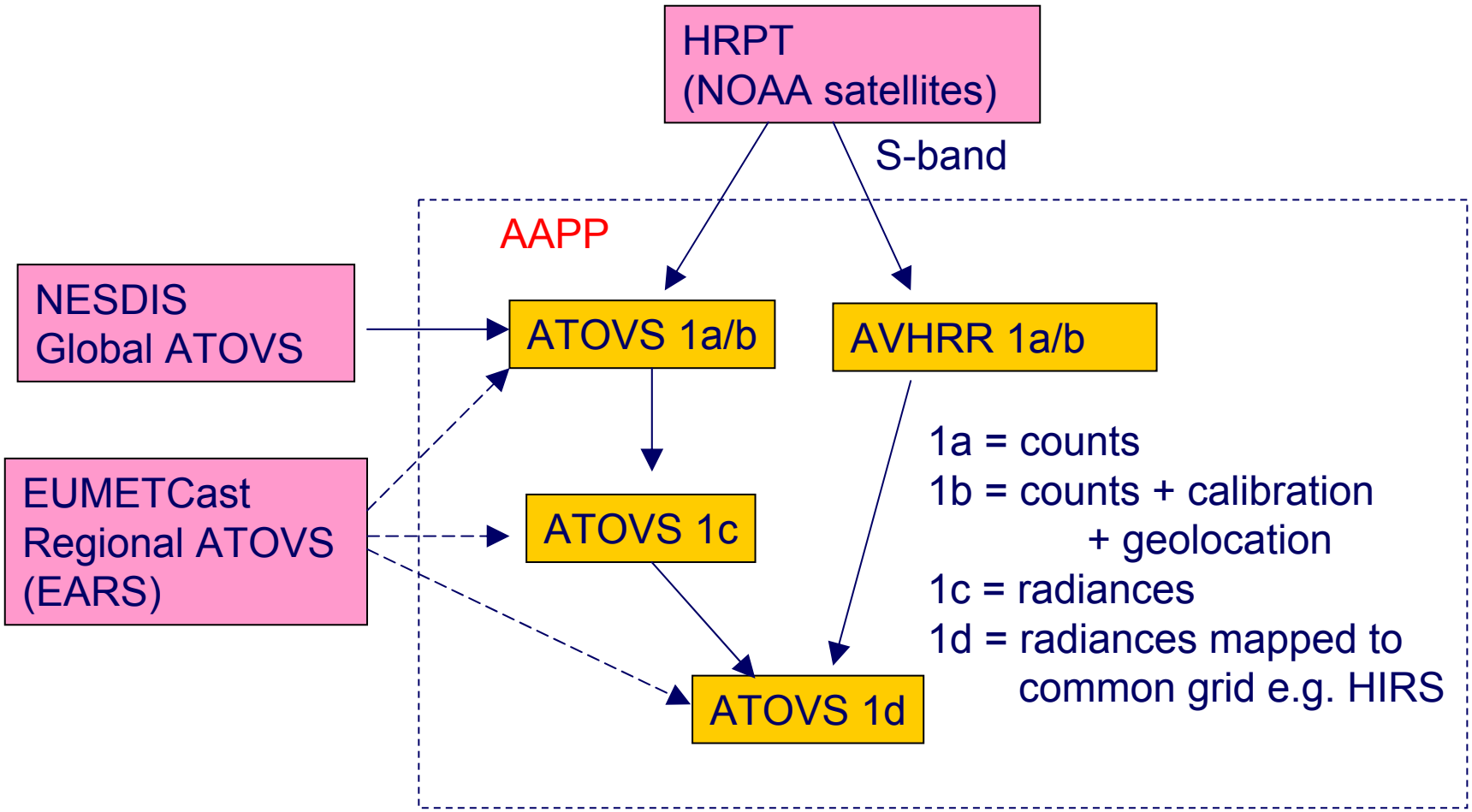
# The NWP SAF: AAPP



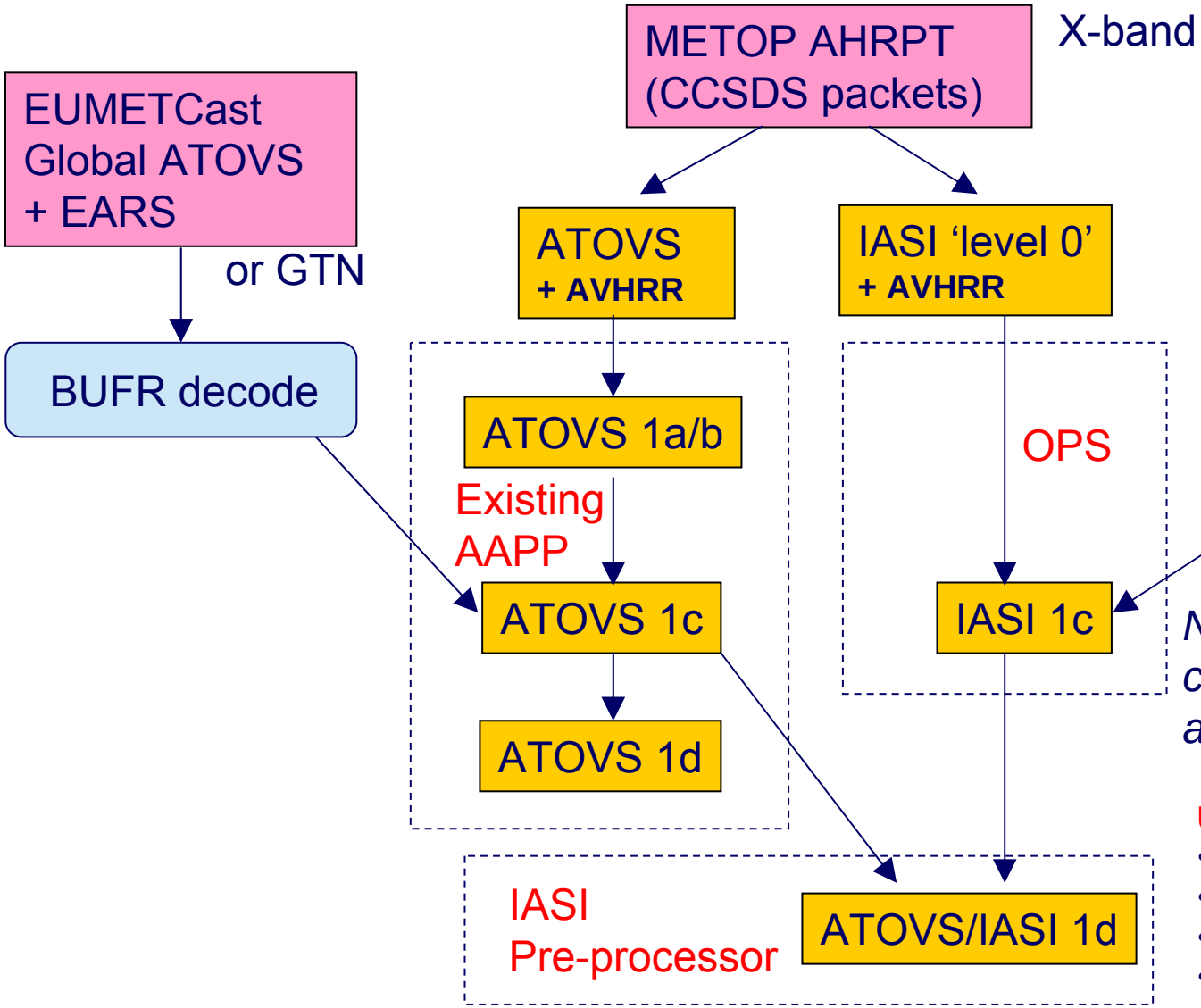
## The ATOVS and AVHRR Pre-processing Package

- Performs **INGEST** and **PRE-PROCESSING** of ATOVS and AVHRR data
  - **ATOVS** = AMSU-A + HIRS + AMSU-B/MHS
- **INGEST**
  - Decommutation
  - Navigation
  - Calibration
- **PRE-PROCESSING**
  - Precipitation and cloud detection for microwave instruments
  - Mapping to common grid (e.g. HIRS fields of view)
  - Cloud analysis on AVHRR pixels within each HIRS fov

# AAPP versions 1 to 5



# AAPP version 6 – including METOP




*NB: IASI 1c = calibrated, corrected & Gaussian apodised*

**User options (flexible):**

- **AMSU mapped to IASI**
- **Spatial thinning**
- **Reduced channel set and/or**
- **Eigenvector scores**

# RTTOV

## RTTOV - a fast radiative transfer model

- It is used by NWP centres for several applications (e.g. radiance assimilation, data monitoring, simulated imagery)
- The NWP SAF maintains and distributes recent versions of RTTOV (currently versions 7 & 8)
- The latest version, RTTOV v8, was released in November 2004
- The next version, RTTOV v9, is now under development and will be released in Feb 2007

# RTTOV functionality

- **Input profiles**: temperature and water vapour; optionally, ozone and carbon dioxide also as variable gases
- **Computes** top-of-atmosphere radiances, brightness temperatures and layer-to-space transmittances for each channel
- **Comprises**: forward, tangent linear, adjoint and K (Jacobian matrix) models, for use in variational assimilation or retrievals
- **Sea-surface emissivity**: computed internally (ISEM-6 model for IR, FASTEM for MW) or value provided by user
- **Clouds**:
  - Single-layer, spectrally-invariant
  - Multi-layer, spectrally-varying: using “wrapper” code, RTTOV_CLD
  - Microwave, with scattering: using “wrapper” code, RTTOV_SCATT
- **Fortran-90**
- Run under **unix or linux**; tested on range of platforms
- **Run-time**: ~ 0.5 *ms* for 20 HIRS channels for 1 profile on HP workstation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# RTTOV – sensors supported

| Platforms | Sensor | Channels simulated |
|---|---|---|
| TIROS-N<br>NOAA-6-18<br>NOAA-2-5 | HIRS, MSU,<br>SSU, AMSU-A<br>AMSU-B, MHS,<br>AVHRR, VTPR | 1-19, 1-4<br>1-3, 1-15<br>1-5, 1-5,<br>1-3,1-8 |
| DMSP F-8-15 | SSM/I | 1-7 |
| DMSP F-16 | SSMI(S) | 1-24 |
| Meteosat-2-8 | MVIRI<br>SEVIRI | 2<br>4-11 |
| GOES-8-12 | Imager<br>Sounder | 1-4<br>1-18 |
| ERS-1/2<br>ENVISAT | ATSR<br>AATSR | 1-3<br>1-3 |
| GMS-5, MTSAT | Imager | 1-3,1-4 |
| Terra<br>Aqua | MODIS,AIRS<br>AMSU-A, HSB, AMSR | 1-17, 1-2378<br>1-15, 1-4,1-14 |
| TRMM | TMI | 1-9 |
| Coriolis | WindSat | 1-10 |
| FY-1, FY-2 | MVISR, VISSR | 1-3, 1-2 |


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# RTTOV-85/87 status

- Number of licence requests = 187
- Number of users provided code ~ 180
- Number of bugs reported since release = 10 for 85 corrected in 87 and 6 for 87 all minor
- Efficient vectorisation of code still being worked on for NEC supercomputer
- Rewritten RTTOV_SCATT code for RTTOV-87
- Participated in AIRS RT comparison (see separate talk)

# New coefficient files available

- METOP n.b. satellite id=2
  - IASI available for RTTOV-7 and 8
  - HIRS available
  - AMSU-A/MHS available
  - AVHRR available
- MSG-2 SEVIRI available
- GOES-12 sounder available
- MegaTropiques, Saphir and Madras

# RTTOV-9 developments

## What is included?

- **New diverse profile dataset – inclusion of more minor gases, more levels**
- **Inclusion of multiple scattering for cloudy and aerosol radiance calculations**
- **Linear in tau mean path values**
- **Zenith angle dependence of path**
- **Include reflected solar for SWIR**
- **More active trace gases CO, $CH_4$, $N_2O$,**
- **Further optimisation of predictors**
- **Improvements to RTTOV_SCATT (new Mie tables)**
- **Change interface to allow profile input on user levels**
- **Change interface to avoid need to specify polarisation index**

# 1D-VAR

# The NWP SAF: 1D-Var schemes

## One-dimensional variational retrieval – 1D-Var

Used for:

- Retrieval of atmospheric/surface variables from radiance measurements
- NWP data assimilation – pre-processing and quality control
- Research tool – rapid exploration of new data

# Variational data assimilation

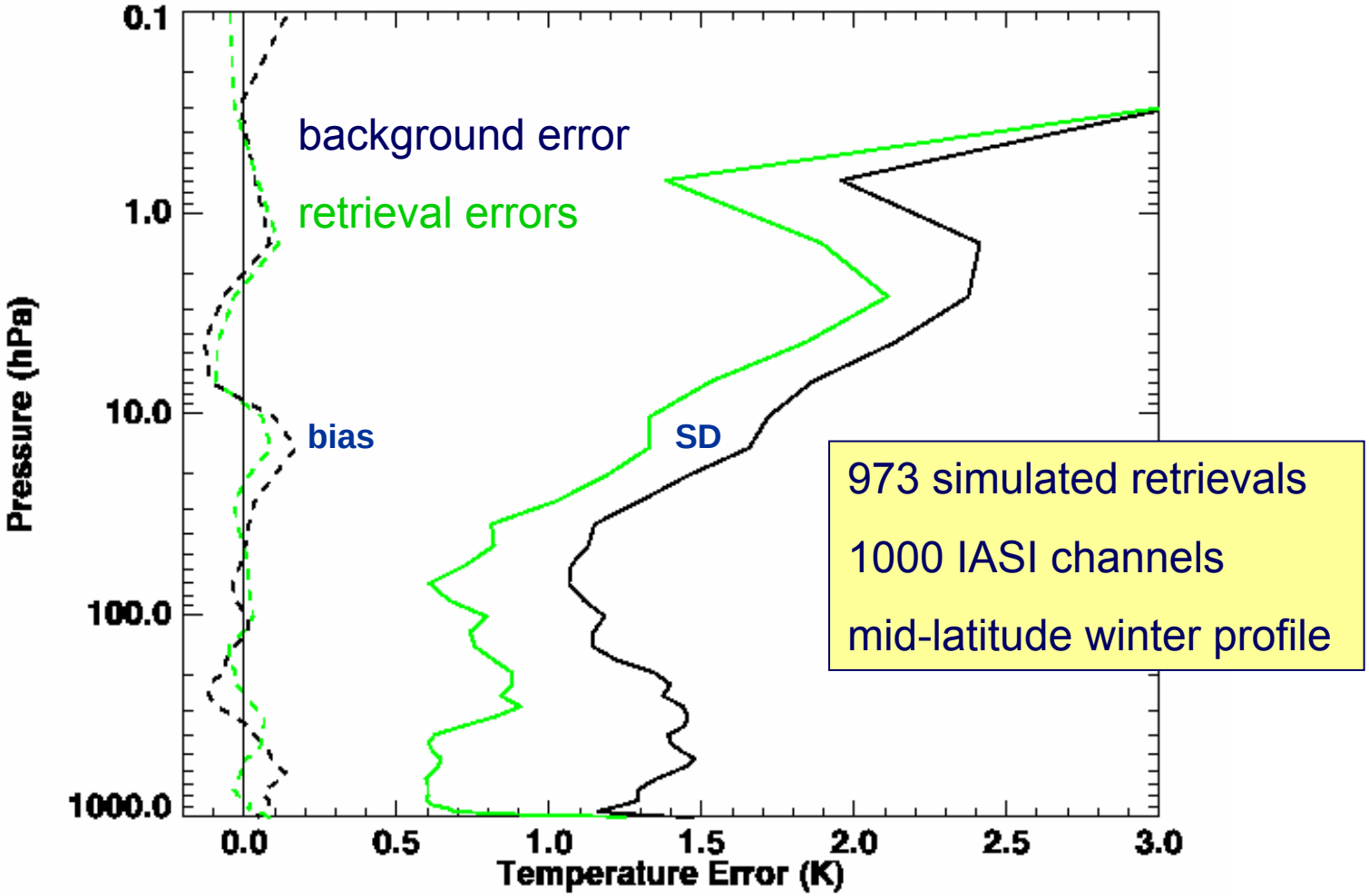
Minimize:

$$J(x) = \tfrac{1}{2}(x-x^b)^T B^{-1}(x-x^b) + \tfrac{1}{2}(y^o-H[x])^T (E+F)^{-1}(y^o-H[x])$$

where x contains the NWP model state
$x^b$ is background estimate of x (short-range forecast)
B is its error covariance,
$y^o$ is vector of measurements
H[...] is "observation operator " or "forward model",
mapping state x into "measurement space"
E is error covariance of measurements,
F is error covariance of forward model.

$$\nabla_x J(x)^T = B^{-1}(x-x^b) - \nabla_x H[x]^T (E+F)^{-1}(y^o-H[x]) = 0$$

# 1D-Var: simulated IASI retrieval errors




973 simulated retrievals

1000 IASI channels

mid-latitude winter profile

# The NWP SAF: 1D-Var schemes

3 schemes are available:

- "ECMWF"
  - generic harness – minimisation scheme with "hooks"
- "Met Office"
  - complete scheme - ATOVS, AIRS, IASI
- "SSMIS"
  - complete scheme - SSMI, SSMIS, AMSU

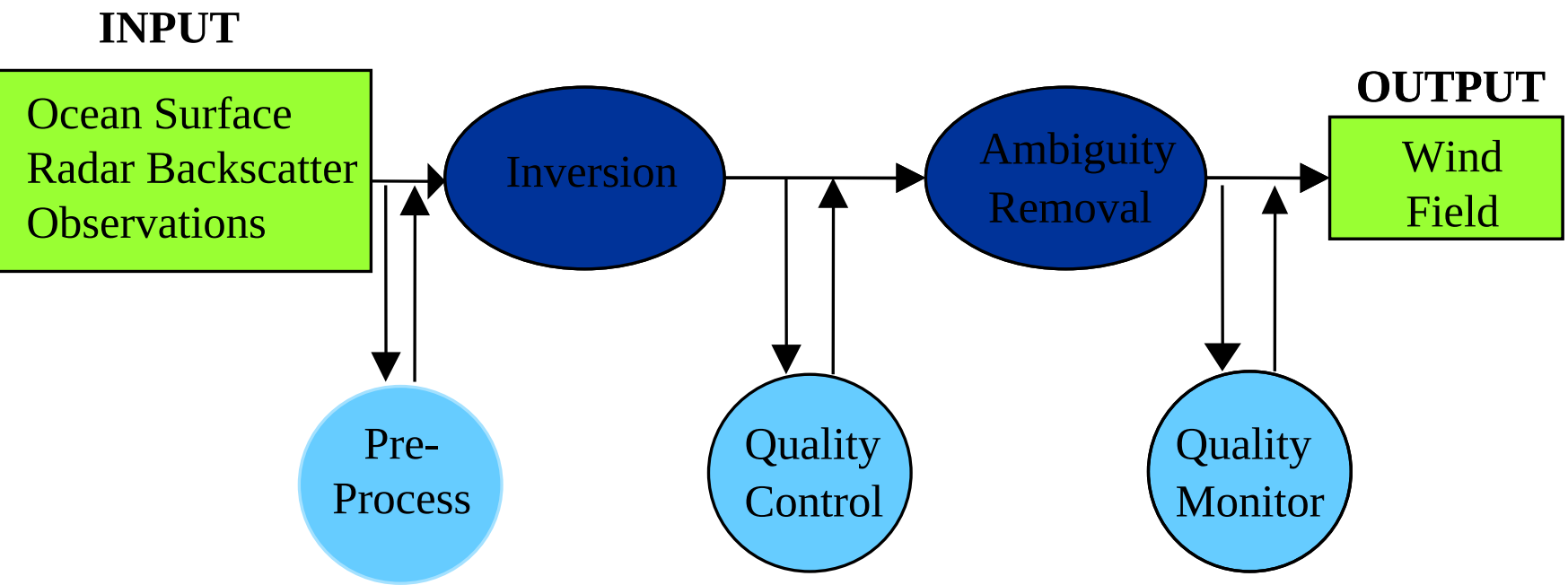
# QDP / SDP

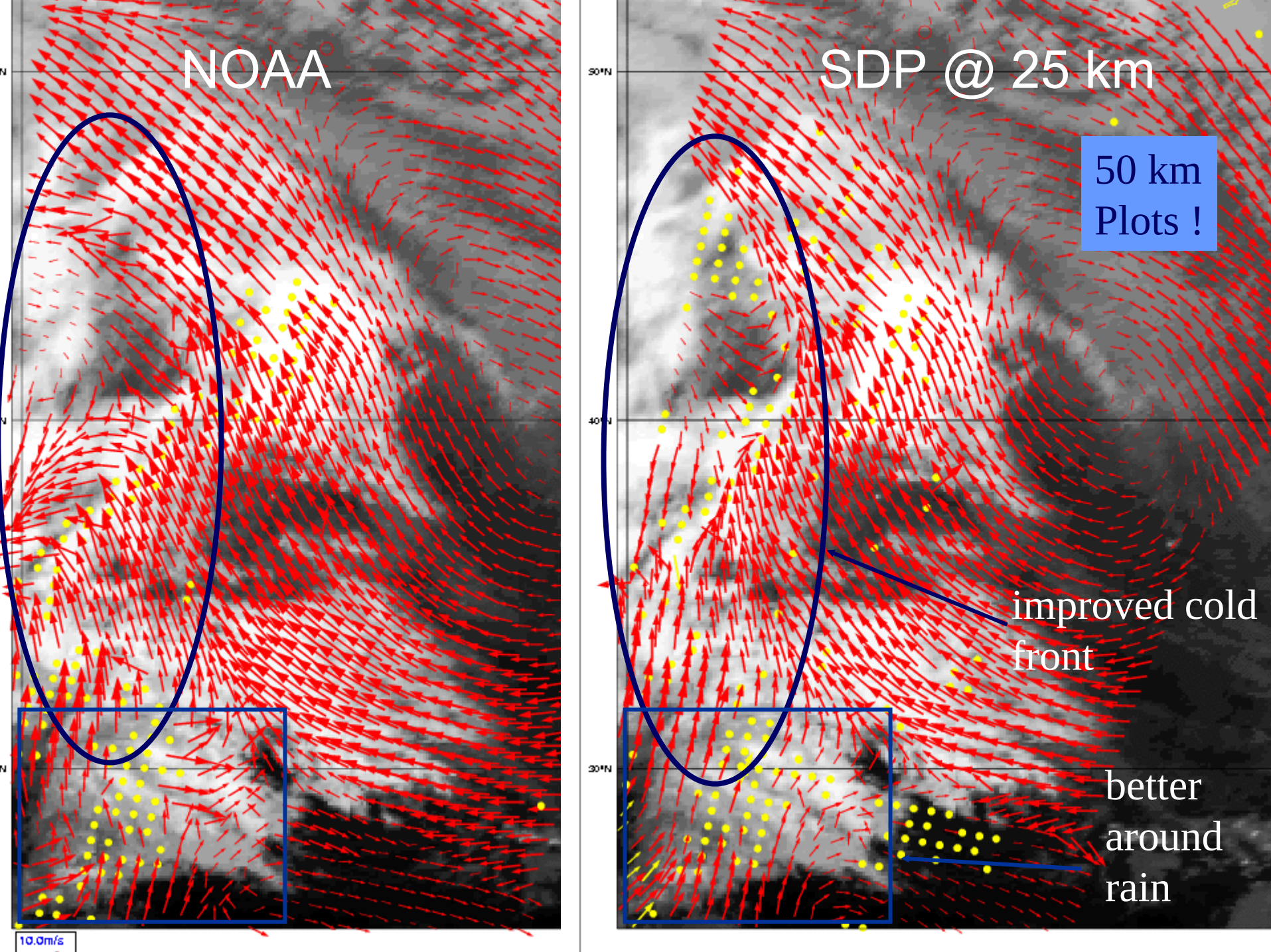
# The NWP SAF: Scatterometer processors

- **QDP** - Quikscat Data Processor – **available NOW**
  - Input – NOAA Quikscat product in BUFR
  - Pre-processing – sorting and spatial averaging
  - Wind retrieval
  - QC – rain detection, etc
  - Ambiguity removal
  - Monitoring and output

- **SDP** – Scatterometer Data Processor - **SOON**
  - Generic scatterometer code
  - ERS SCAT, METOP ASCAT, Seawinds (Quikscat, NSCAT)

# Scatterometer Data Processor




NOAA
SDP @ 25 km
50 km
Plots !
improved cold
front
better
around
rain
10.0m/s

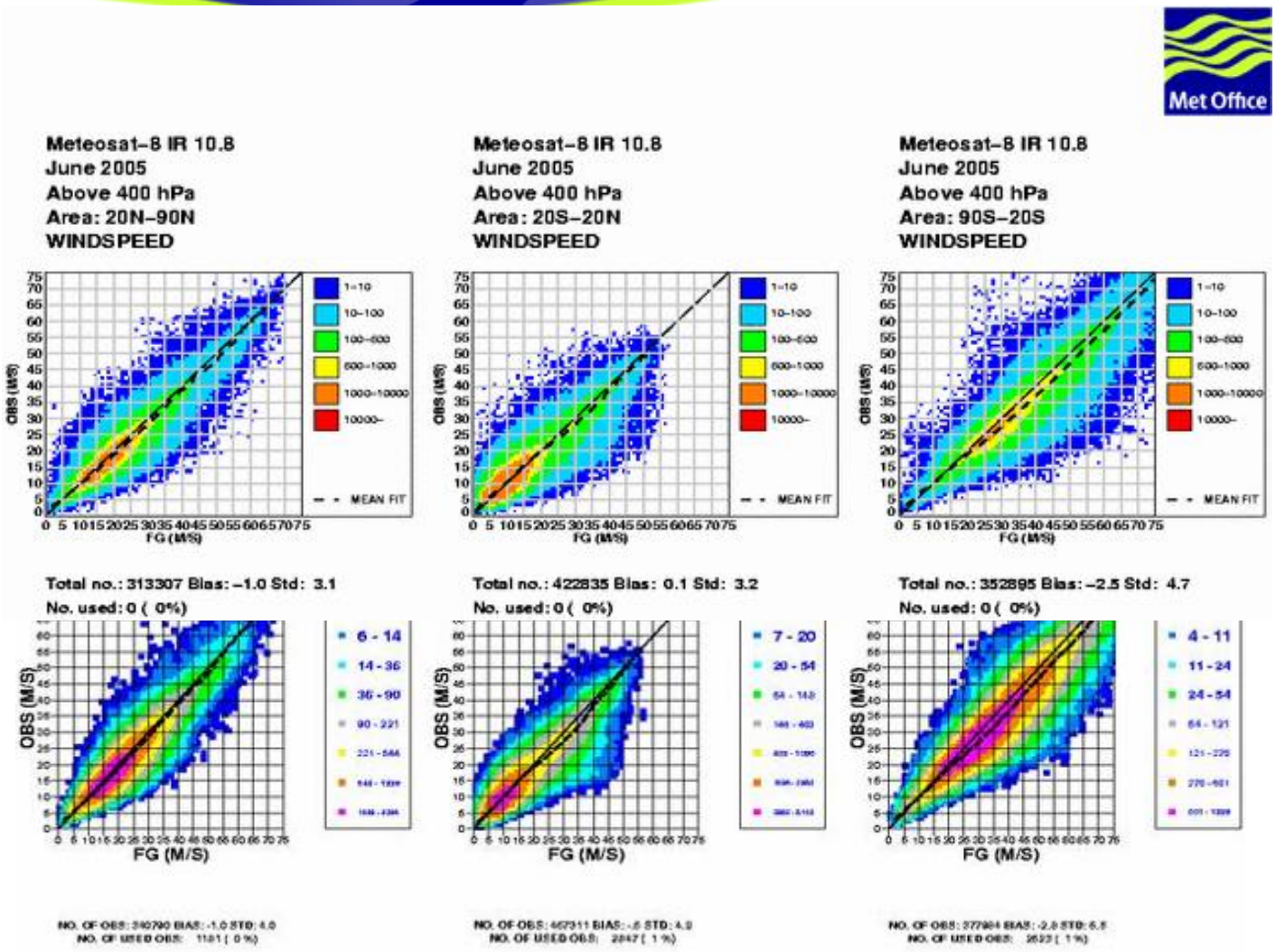
# Monitoring reports

# The NWP SAF: monitoring products

- Observation coverage plots
- Statistics of observed-forecast differences

- Data types:
  - ATOVS, SSMI, AIRS, geo-radiances
  - AMVs
  - Quikscat, ERS-2
  - Ozone: SBUV, Envisat

# The NWP SAF: monitoring products



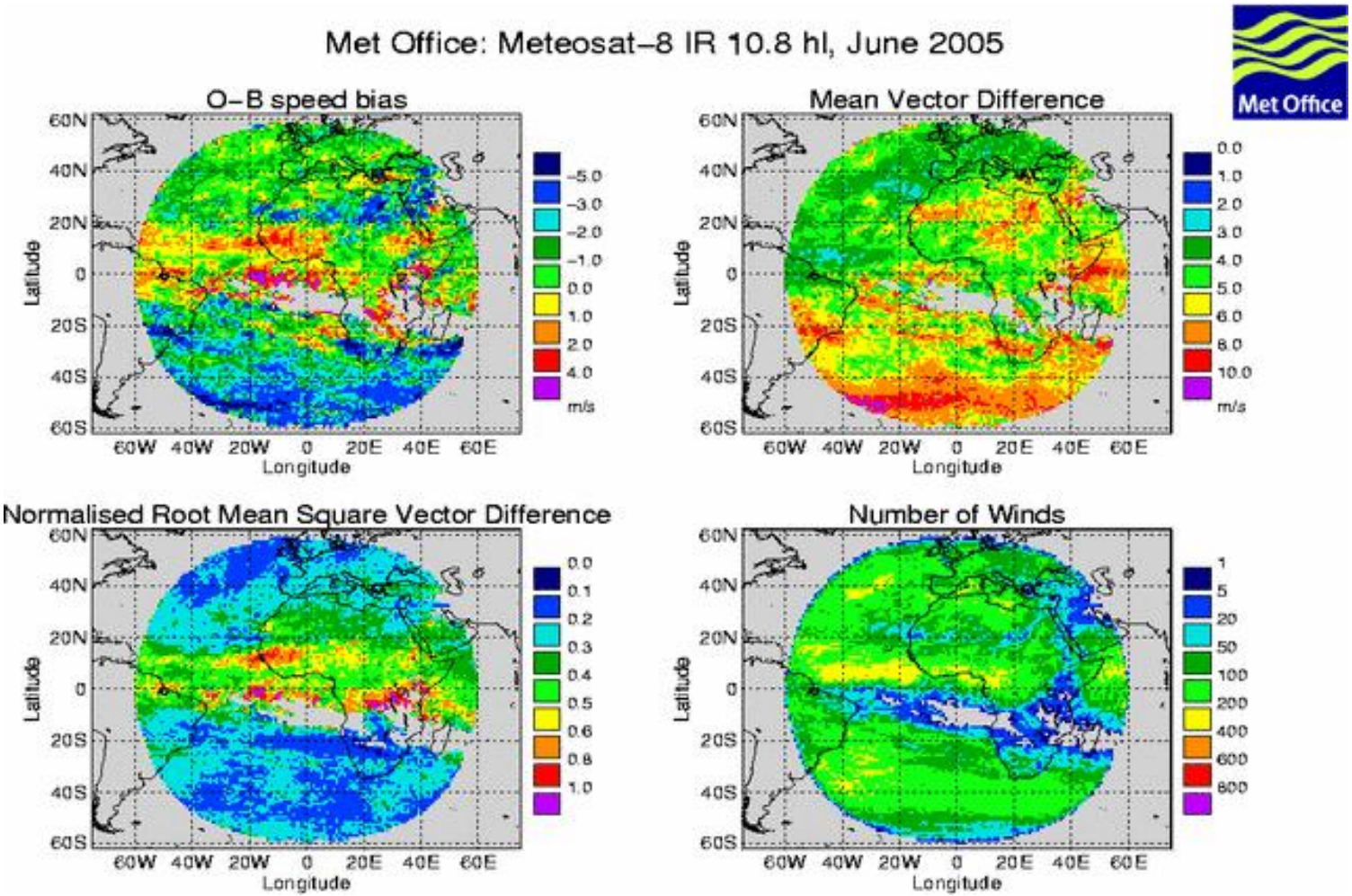

Example:

AMVs v. 6h forecast

Met Office

ECMWF

# The NWP SAF: monitoring products

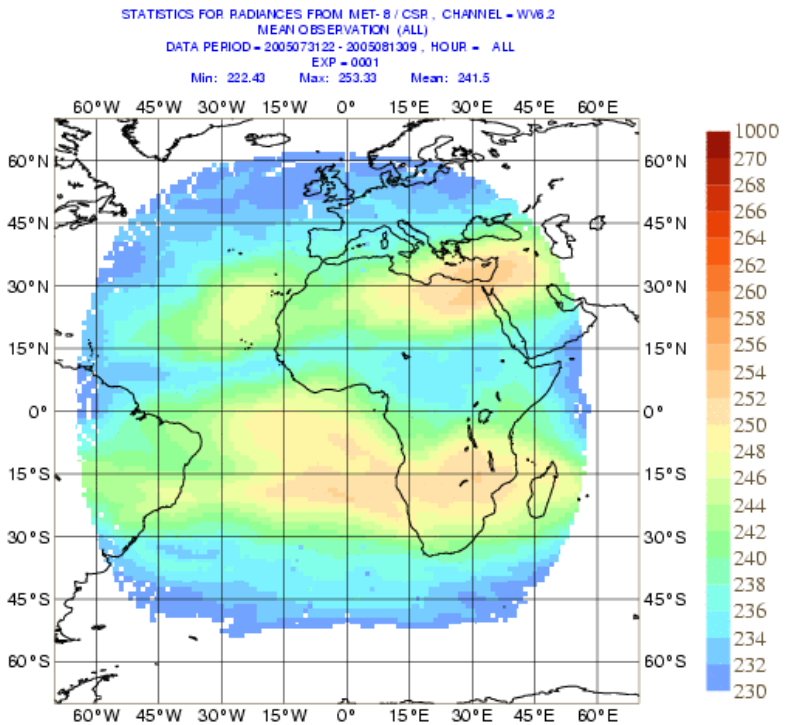


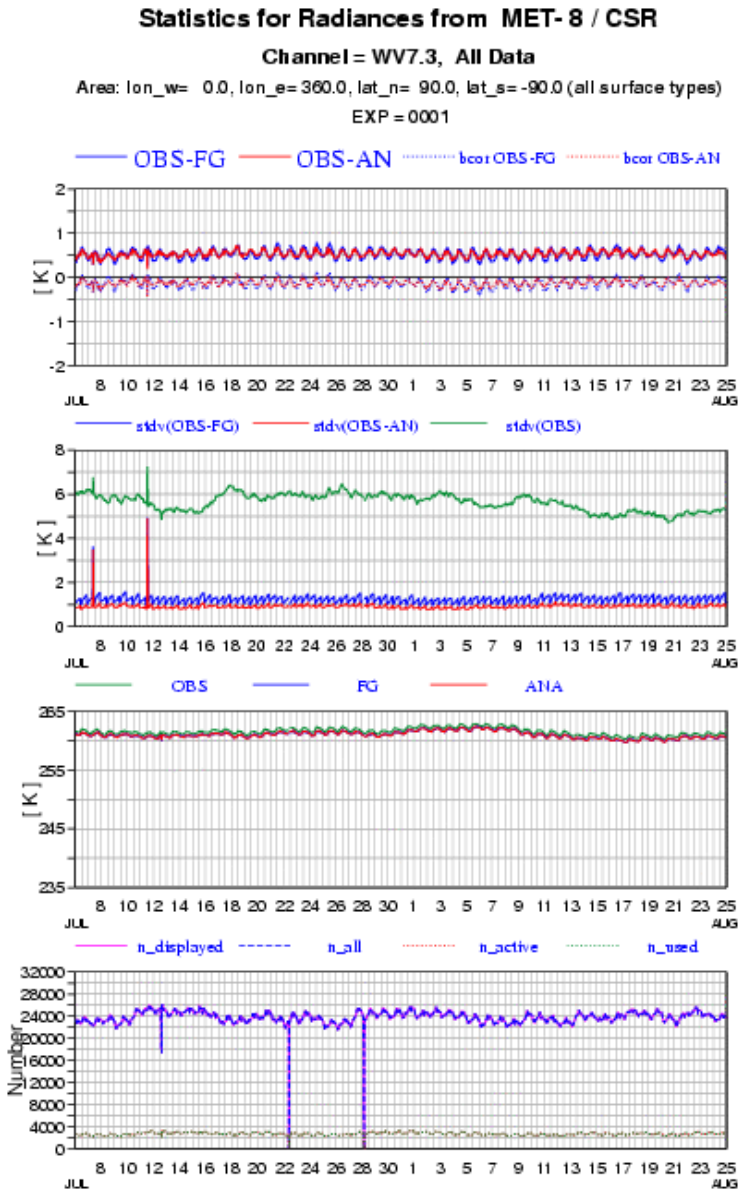

Example:

AMVs v. 6h forecast

Met Office

# The NWP SAF: monitoring products



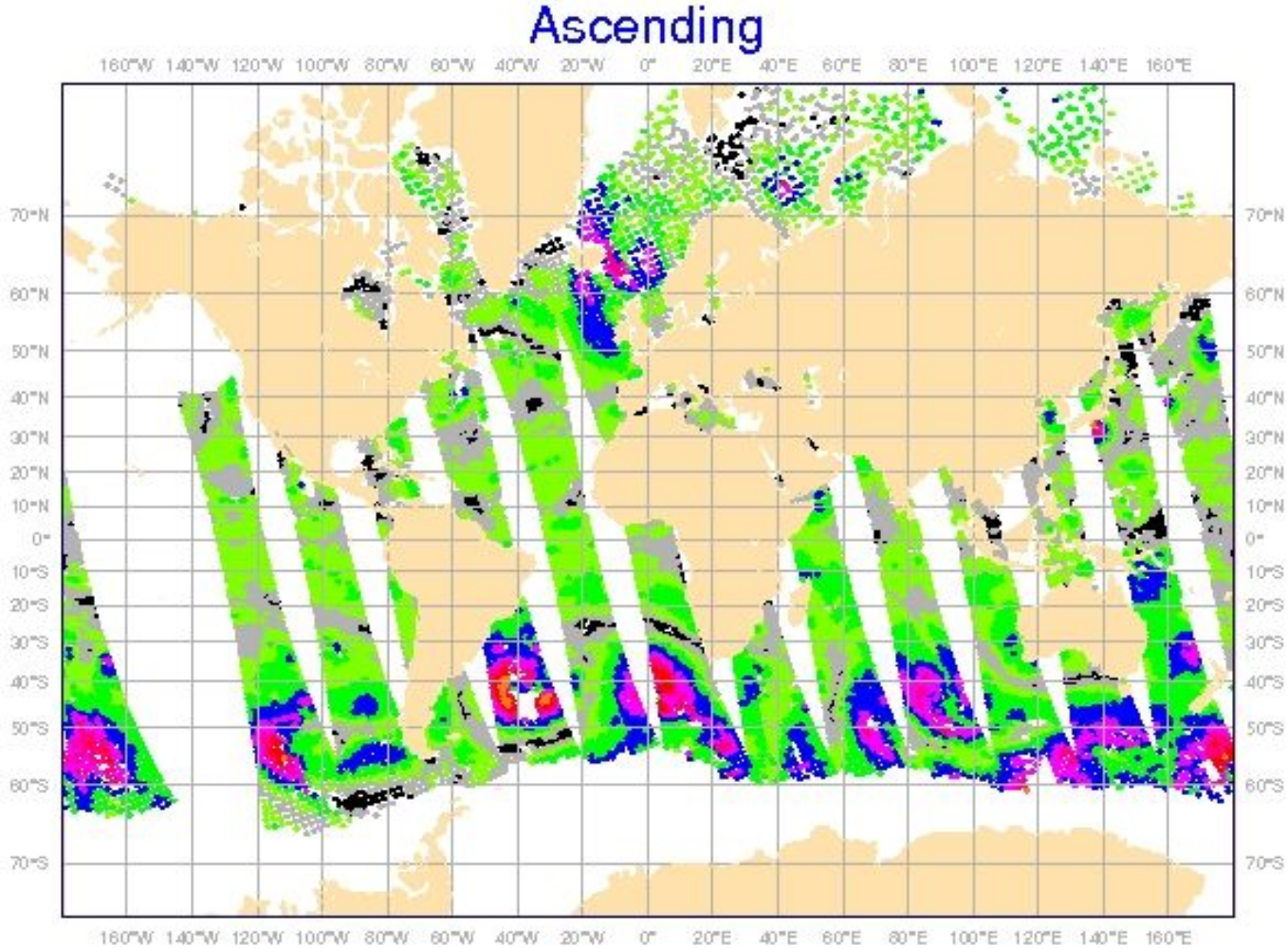




Example:

MSG 6.3µm water vapour channel

ECMWF

# The NWP SAF: monitoring products




Example of link to another monitoring site:

KNMI Quikscat monitoring

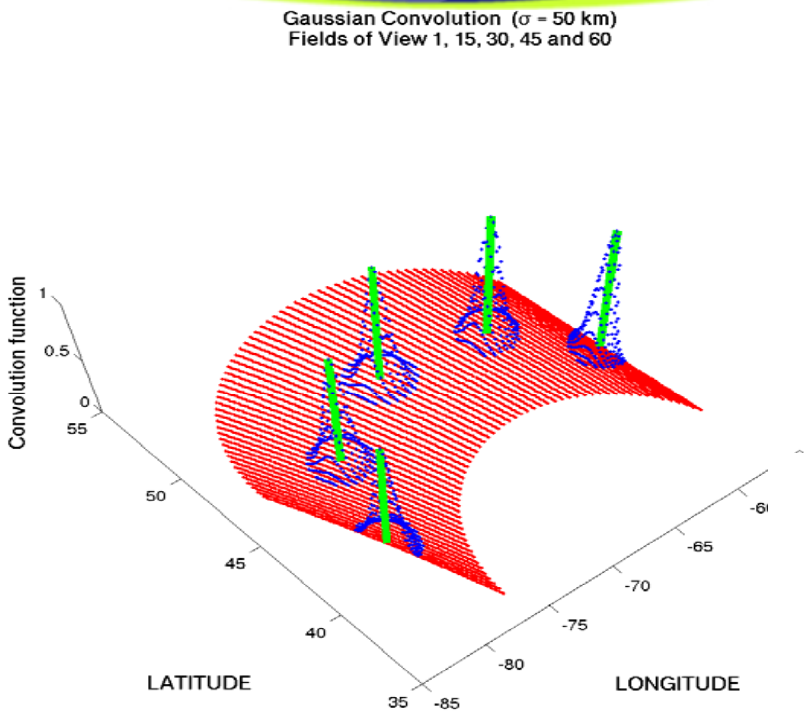
# SSMIS Preprocessor

Main functions:

- Remapping
- Averaging
- Reflector emission correction
- Solar intrusion flagging

Code & preprocessed data available

# SSMIS Preprocessor : Averaging

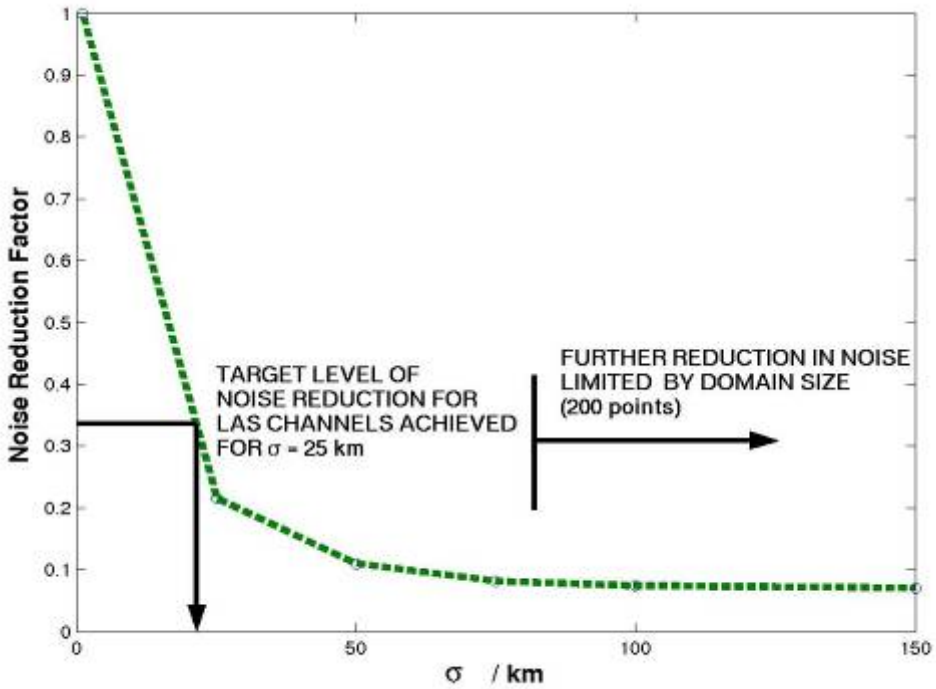



- Operational preprocessor uses σ = 50km (FWHM = 118km)
- $NE\Delta T_{eff}$ ~ 0.03K
- Processing time ~ 1 minute/ orbit

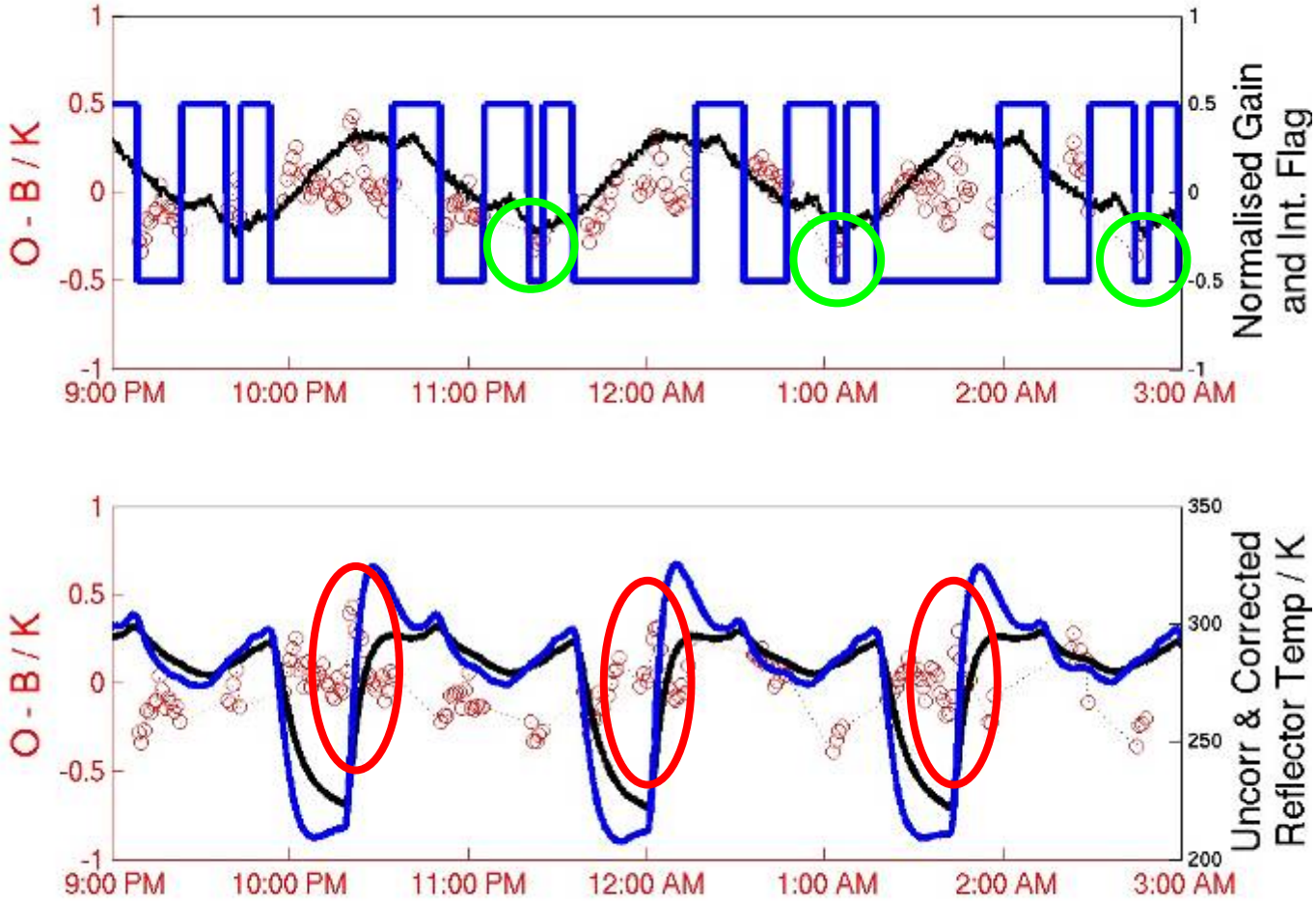
- $NE\Delta T$ for LAS channels is ~0.3K

⇒require averaging to achieve $NE\Delta T_{eff}$ = 0.1K

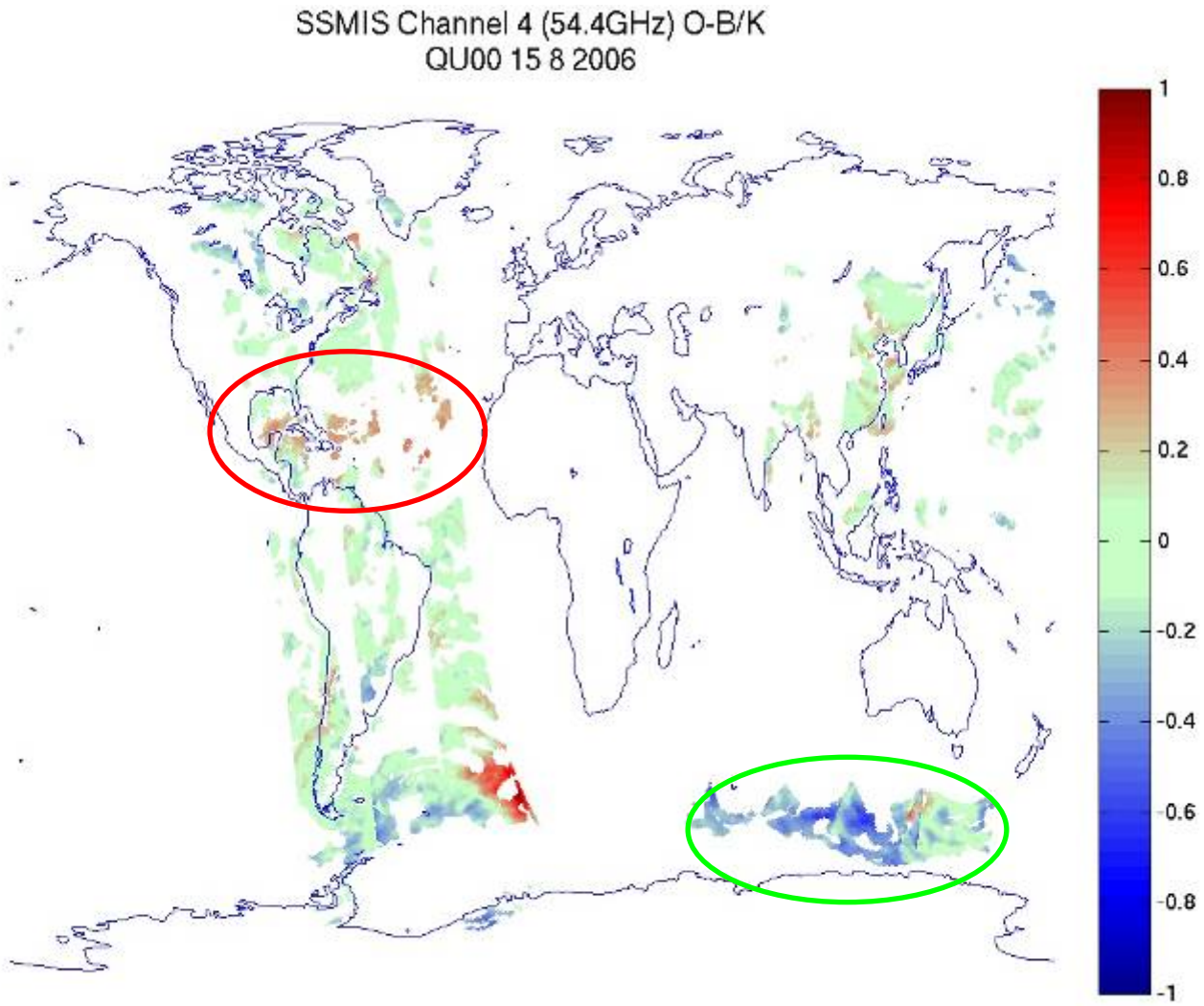
- Also benefit from improved scale matching?



# SSMIS preprocessor: flagging and correction residual biases



# SSMIS preprocessor: flagging and correction residual biases



# Support to EARS

## NWP SAF support to the EUMETSAT ATOVS Retransmission Service (EARS):

- Development and maintenance of AAPP
- Real-time data monitoring:
  - for each EARS reception site
  - checks consistency with global ATOVS data
  - checks consistency with locally-received ATOVS data (Lannion)

# Conclusions

# The NWP SAF: concluding remarks

- Collaboration between 4 European NWP centres, with support from EUMETSAT, has permitted the development, delivery and support of:
  - software modules for satellite data processing and assimilation,
  - data monitoring services,

to a large and growing user community.

- Over the next few years, the NWP SAF plans to contribute to the exploitation of data from new instruments.

- Collaboration with the international community will be needed to ensure we cover all the new instruments, in a timely manner, without unnecessary duplication.

# The NWP SAF: further information

- For information, visit:

http://www.metoffice.gov.uk/research/interproj/nwpsaf/index.html

- To obtain software, visit:

http://www.metoffice.gov.uk/research/interproj/nwpsaf/request_forms/index.html

End

# Supplementary slides

# AAPP - Recent updates

## Updates to AAPP v4.0

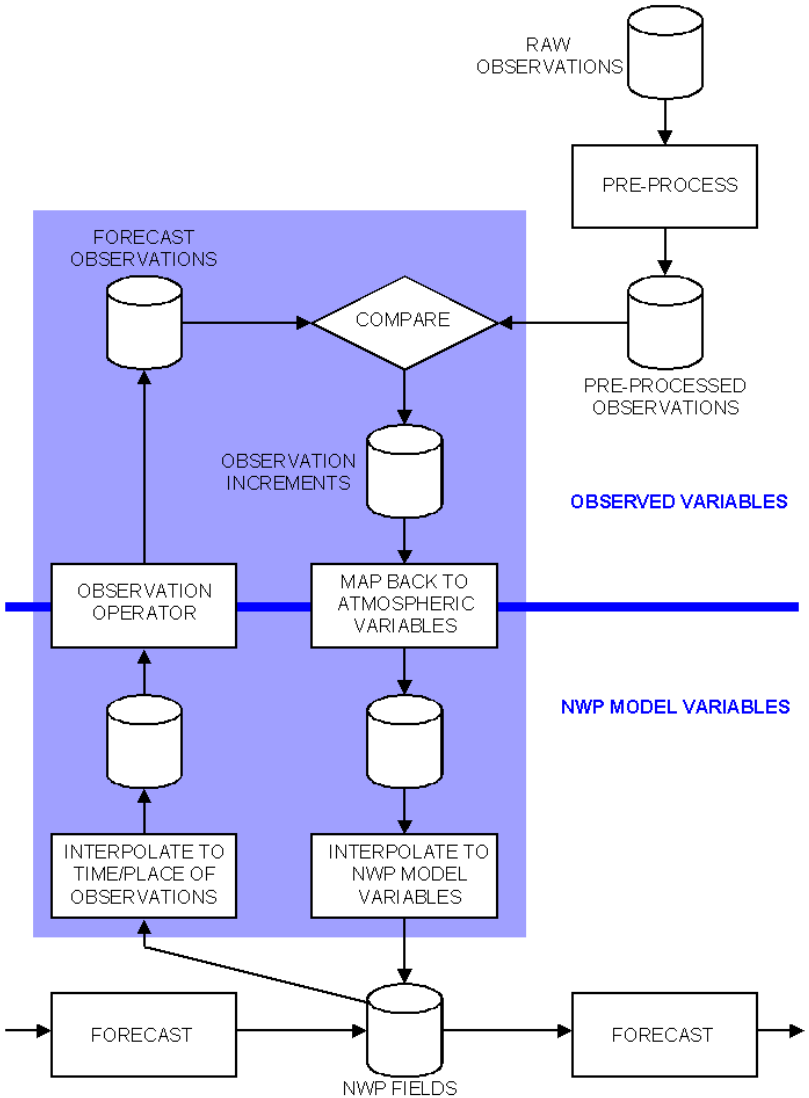
- Update 4.4, 31/8/04:
  - Linux compatibility (also Windows via MS Services For Unix)
  - Improved robustness in decommutation
  - Utility to compare output files from different platforms (*atovsCompare*)
  - Big/little-endian conversions
  - Processing of **NOAA-17** to level 1d
  - 1d flag for fewer collocations than expected in re-mapping AMSU-A to HIRS

- Update 4.5, 03/02/05:
  - Updated AMSU-B calibration parameters file (gross limits)

# AAPP version 5

- Includes the following enhancements:
  - NOAA-N capability (including MHS)
  - New HIRS calibration method (based on NOAA v4)
  - Updated navigation – ability to use 2-line elements
  - Calibration - allow for moon contamination in AMSU-B/MHS
  - Precipitation tests - added NWC-SAF scattering index (Bennartz) to AMSU-B level 1d
  - Use of instrument-specific scan characteristics, and removal of many hard-coded parameters
- Released to users on 18 July 2005, following validation with NOAA-18 data (~2 months after launch)

# The NWP SAF: 1D-Var schemes

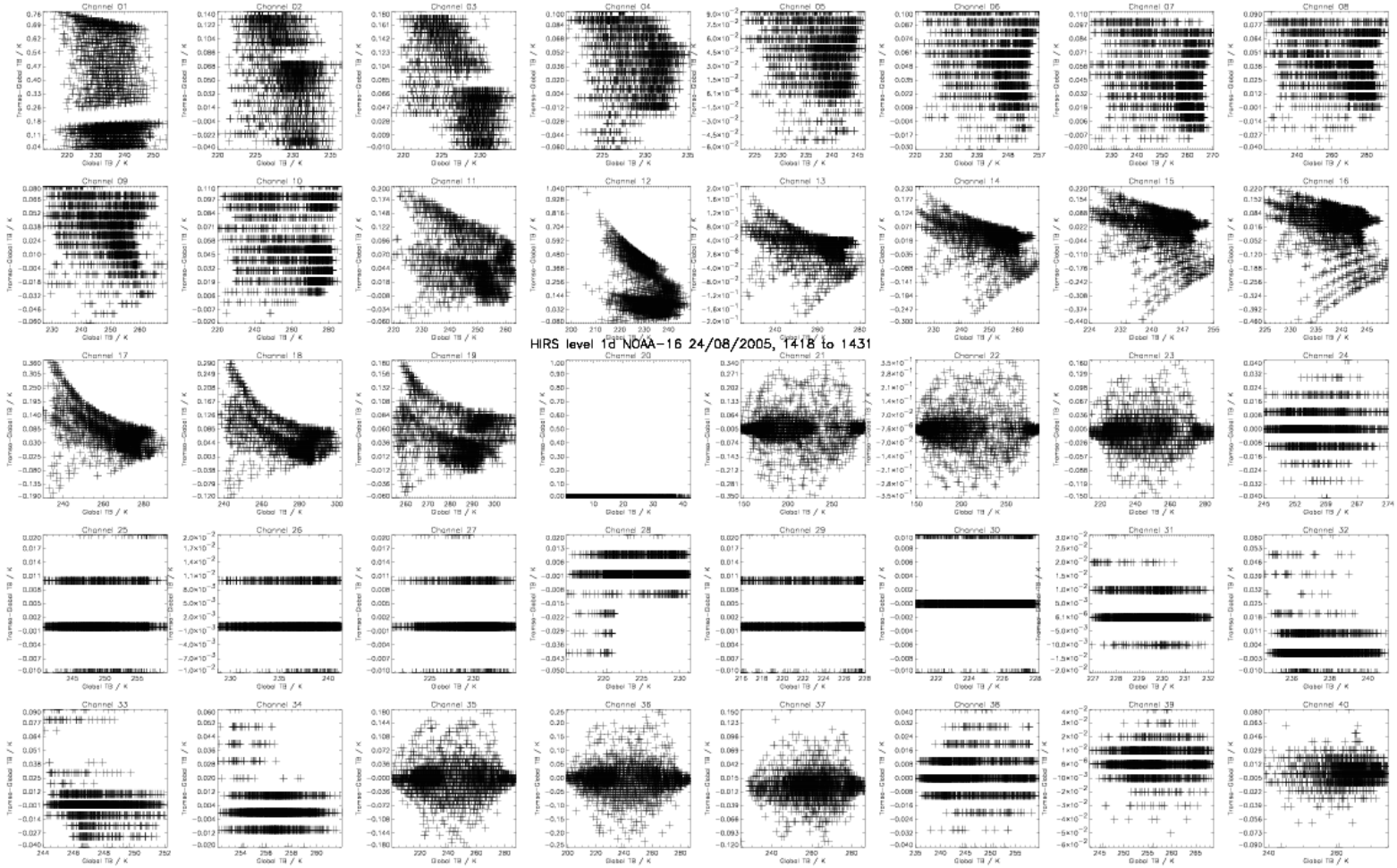



Assimilating observations into a NWP model

OR

Retrieving atmospheric variables using a forecast profile as background (first guess)

# The NWP SAF: monitoring EARS v global radiances




## Example: ATOVS - Tromso